Examples in Advanced Accelerator R&D: path from not believable to routine

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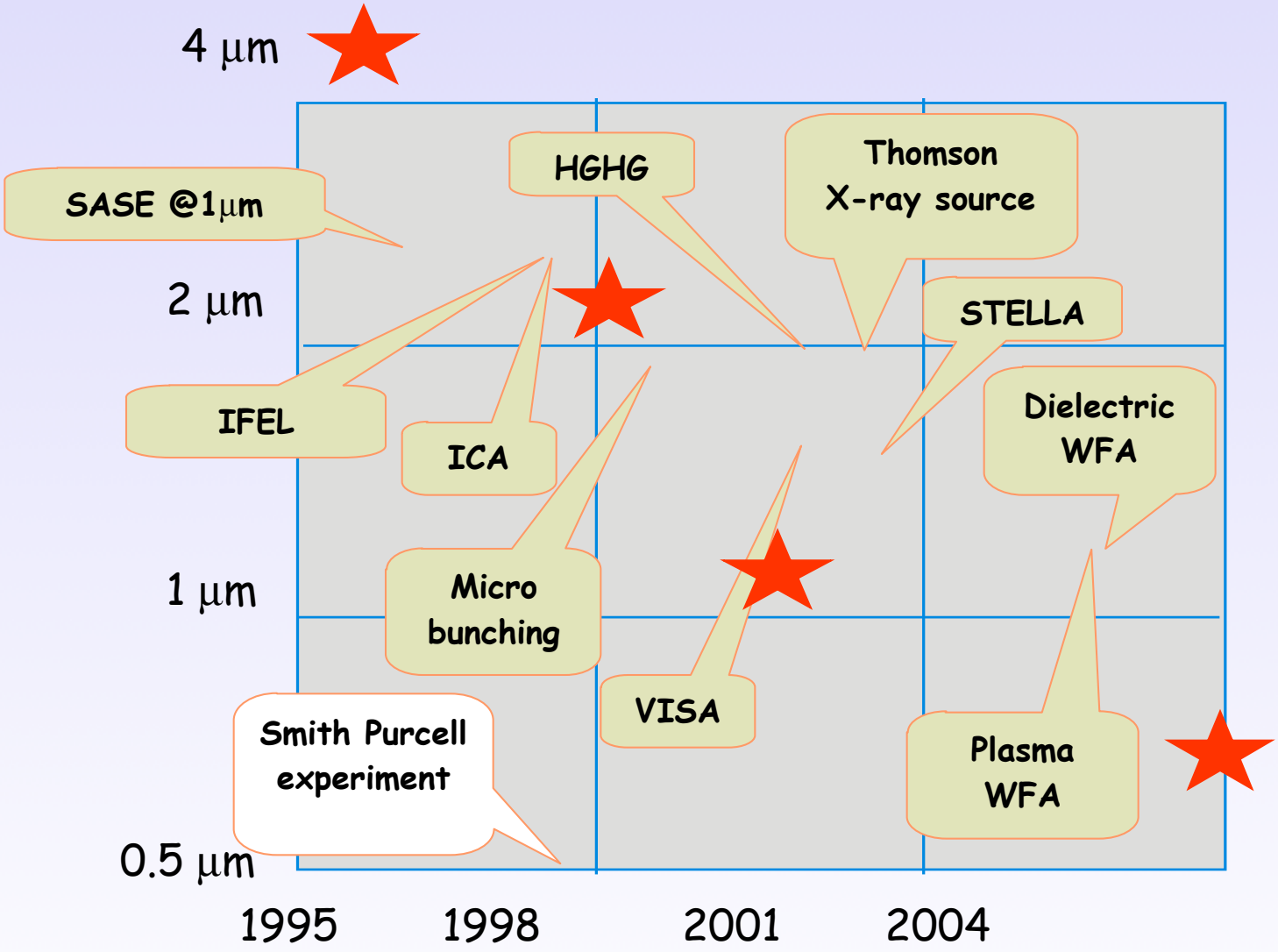
U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

BNL/SLAC/UCLA 1.6cell RF photoinjector



FACET is a National User Facility

Primary Goal: Demonstrate a single-stage high-energy plasma accelerator for electrons.

- Meter scale ✓
- High gradient ✓
- Preserved emittance
- Low energy spread ✓
- High efficiency ✓

Timeline:

- Commissioning (2012) ✓
- Drive & witness e^- bunch (2012-2013) ✓
- Optimization of e^- acceleration (2013-2015)
- First high-gradient e^+ PWFA (2014-2016)

FACET user program is based on high-energy high-brightness beams and their interaction with plasmas and lasers

E200: Plasma Wakefield Acceleration

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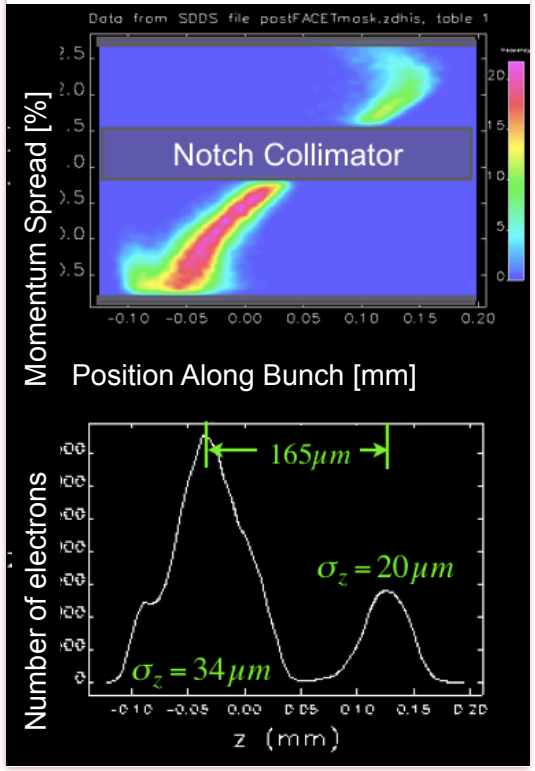
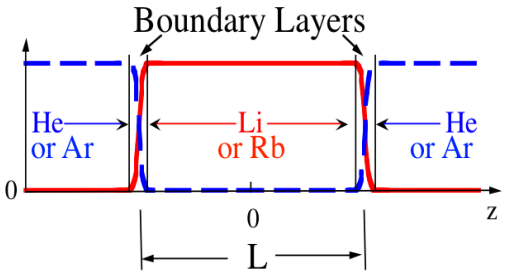
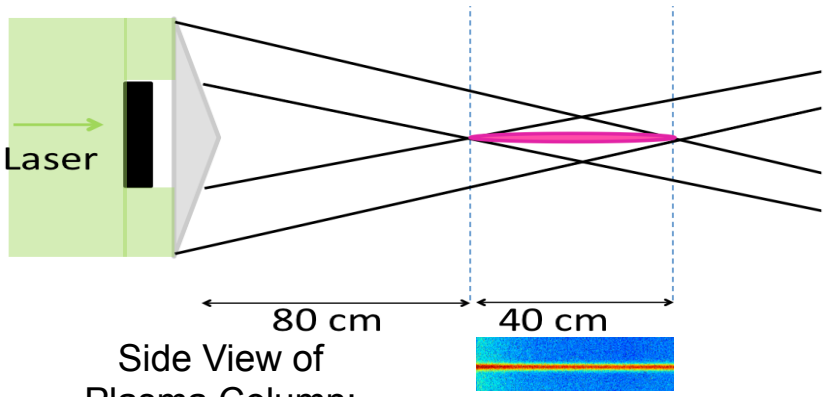
Simulation of Collimated Longitudinal Phase Space



Heat Pipe Oven for uniform column of low ionization potential vapor



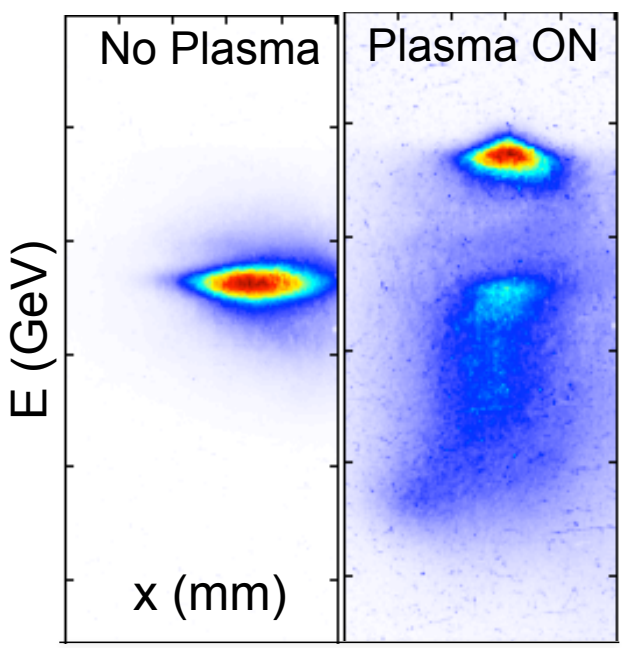
Line focus defines plasma channel aligned onto e⁻ beam orbit



Side View of Plasma Column:

2013

electron density (e^- mm^{-2})



2 GeV Energy Gain
~2% dE/E

Accepted by Nature

Up to 50% energy transfer from drive to witness was measured

First Experiments with GeV/m Positron PWFA

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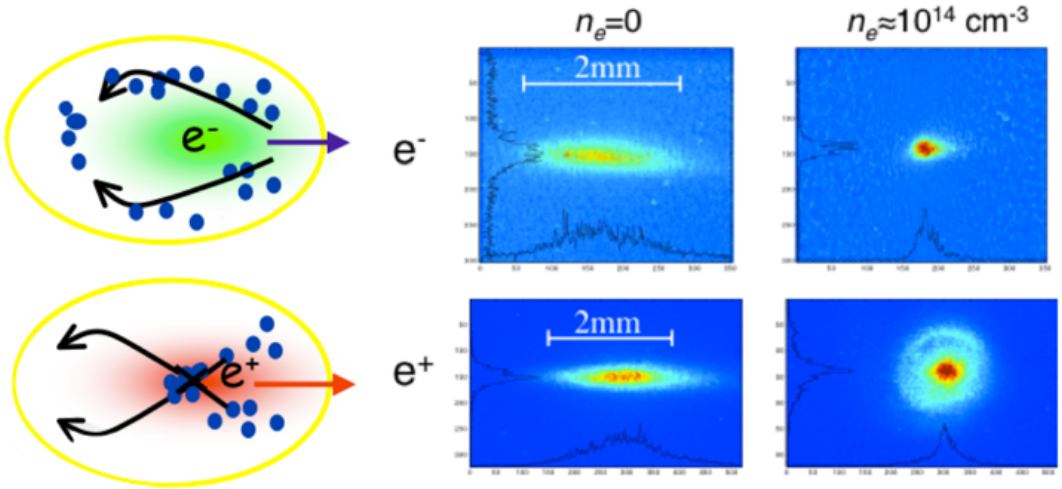
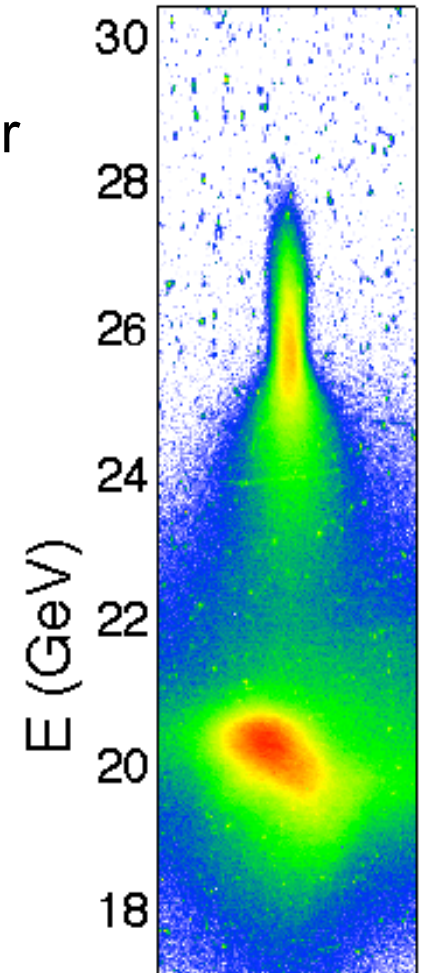
- Early experiments followed rapid commissioning of positrons
- Unanticipated features in the data
  - Beam Quality: Divergence of accelerated positrons similar to electrons, emittance growth less than expected
- Source of active discussions & simulations



Phys. Rev. Lett. **90**, 205002 (2003)

Phys. Rev. Lett. **101**, 055001 (2008)

Log Color Scale



FACET has the only program in the world studying plasma acceleration of positrons

Simulations Providing Insight into Positron Driven Wakes

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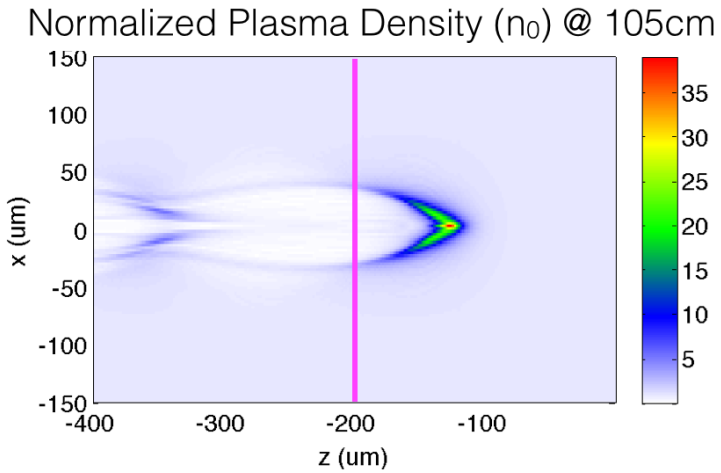
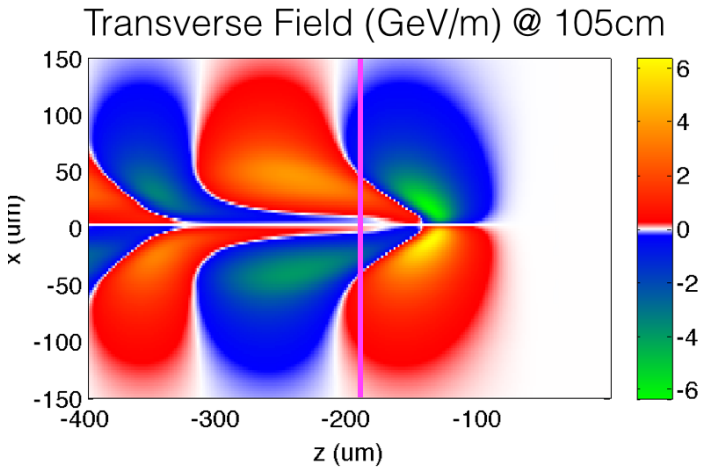
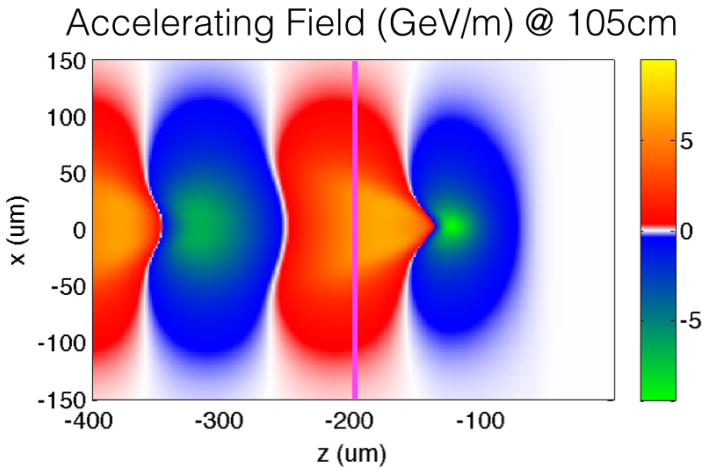
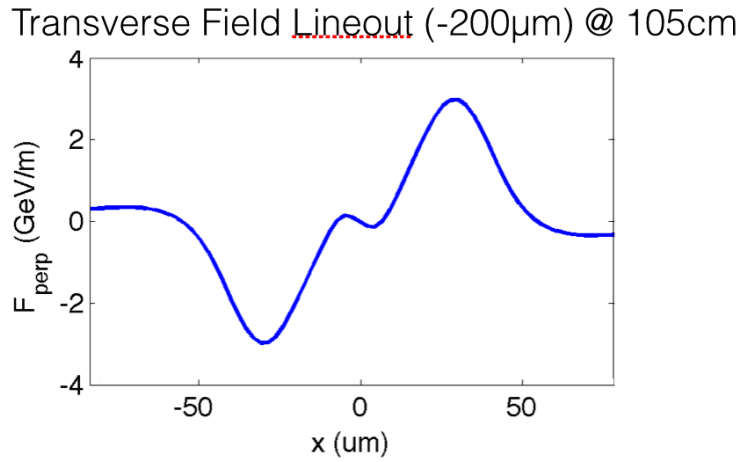
New regime: focusing and accelerating region for positrons in the wake of a positron beam









This study is important for plasma afterburner as an energy doubler

Positrons and Hollow Channel Plasmas

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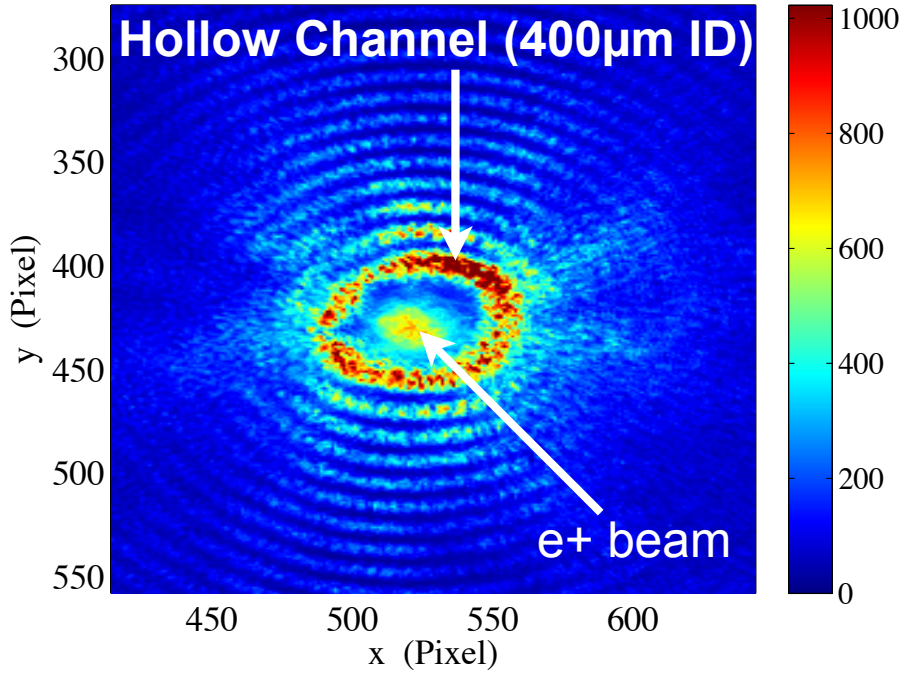
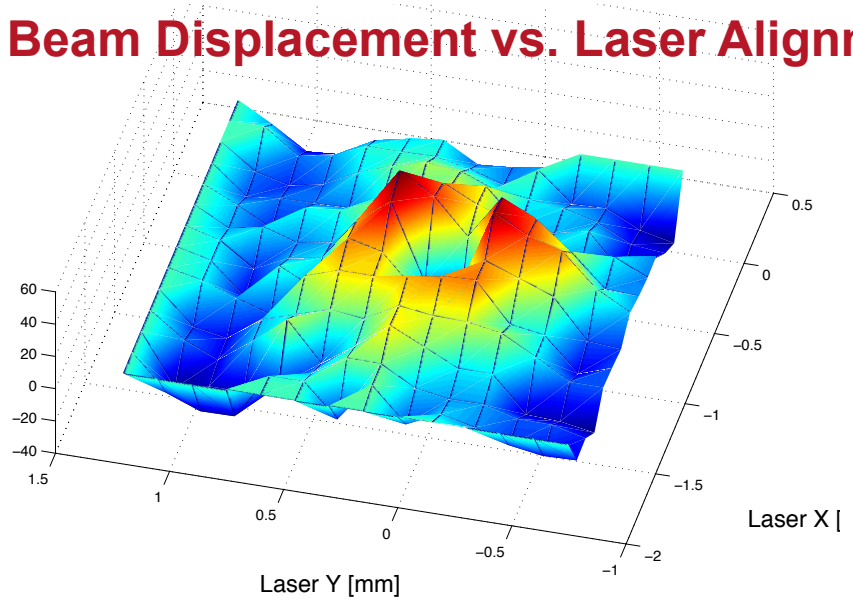
Hollow channel plasmas are considered a viable method for accelerating positrons in electron driven wake



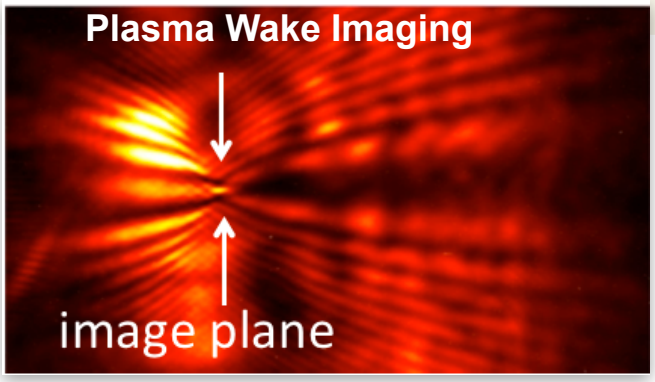
e+ Beam Displacement vs. Laser Alignment

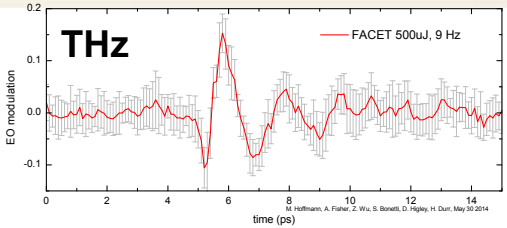


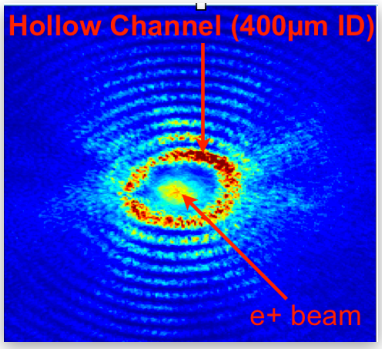
- Several orders of magnitude difference between BBU theory and preliminary experimental data
- Need to improve theory, compare with simulations and experiments

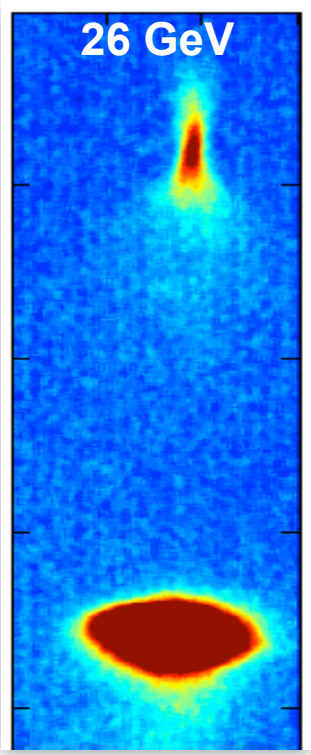
This study is important for e- driven collider stage

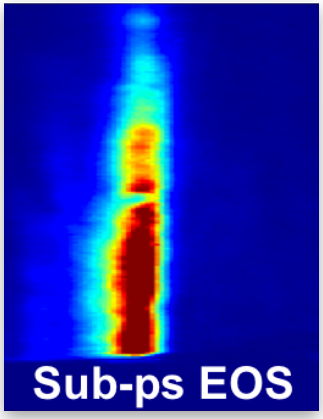
FY14 FACET Run – Fifteen Experiments

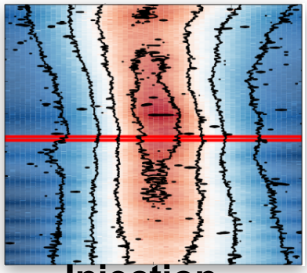


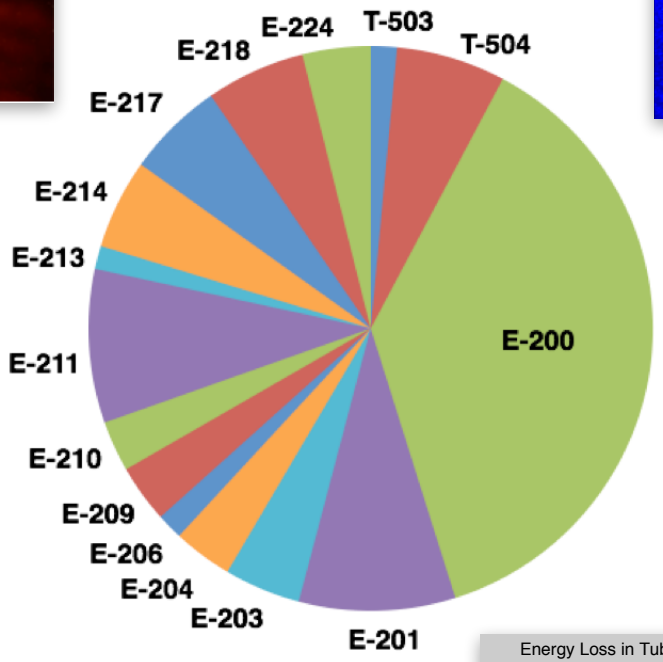


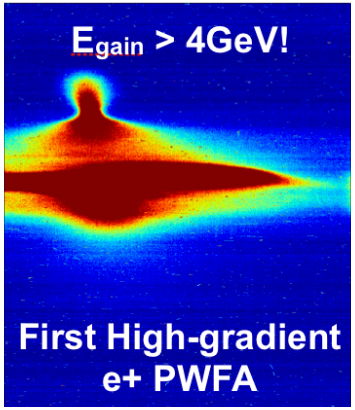


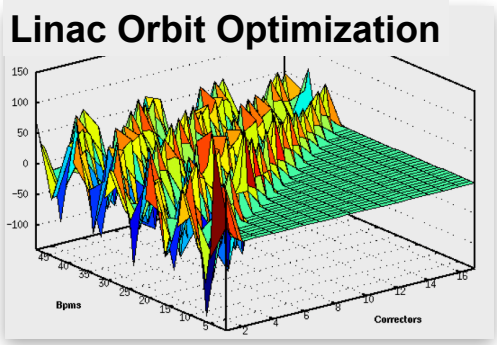


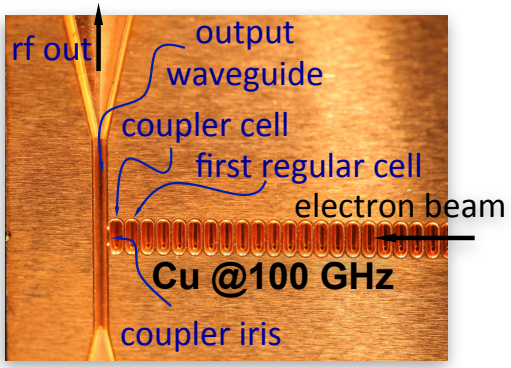


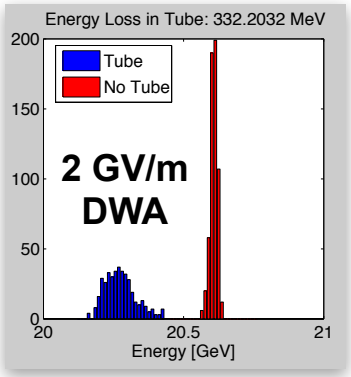


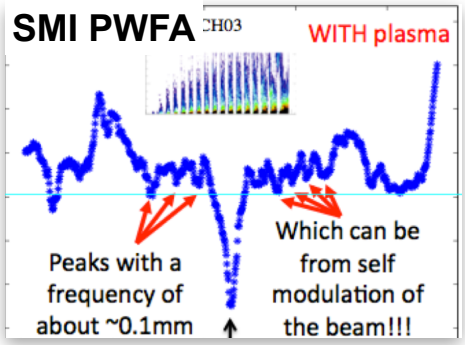






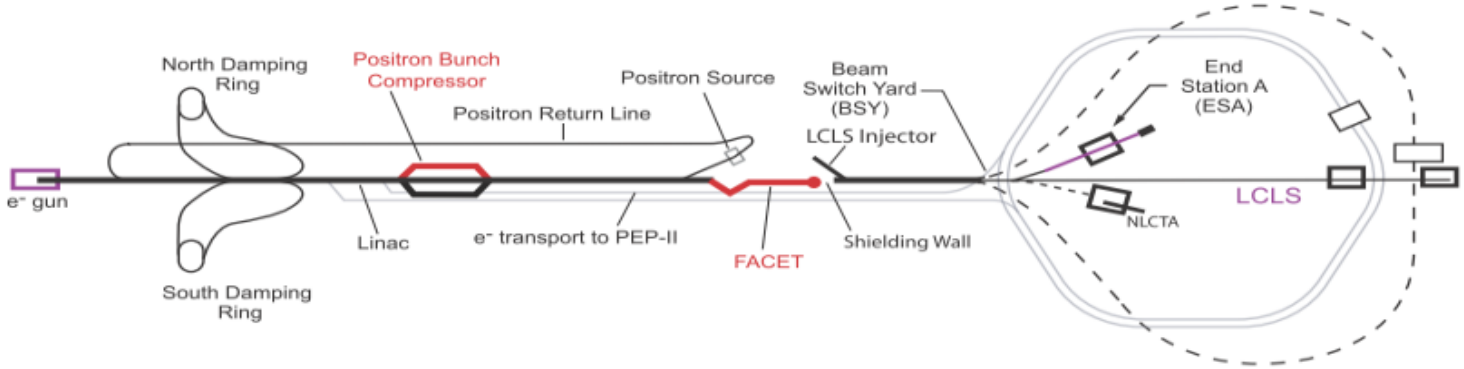




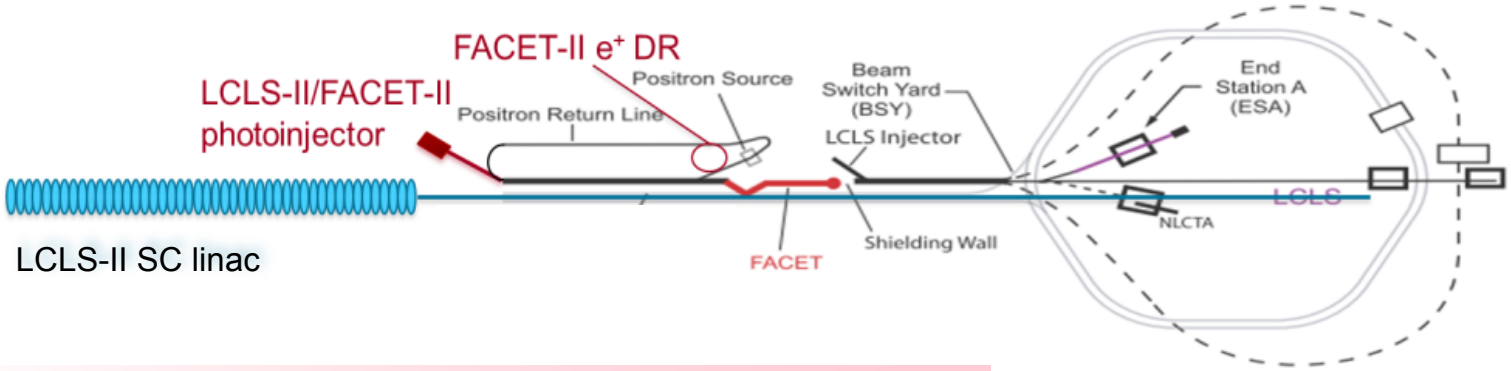


From FACET to FACET-II

FACET today



FACET-II



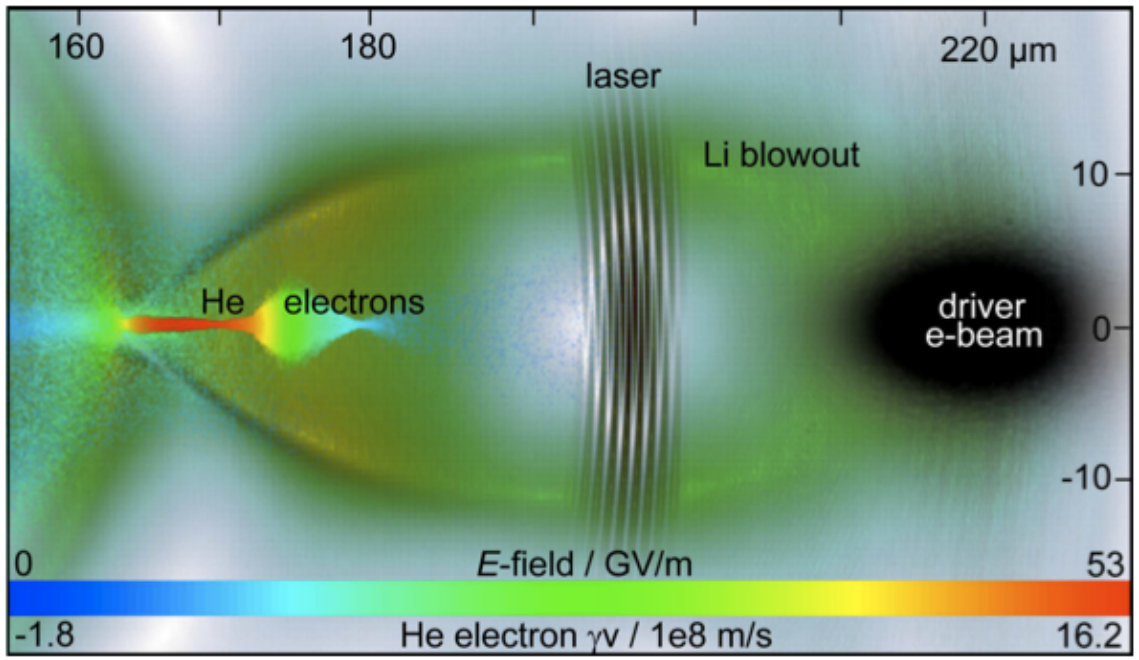
Three main stages:

- electron beam photoinjector (e^- beam only)
- positron damping ring (e^+ or e^- beams)
- "sailboat" chicane (e^+ and e^- beams)

Creating Ultra High-Brightness Beams with PWFA

- Plasma bubble (wake) can act as a high-frequency, high-field, high-brightness electron source
- Photoinjector + 100GeV/m fields in the plasma =
  - Unprecedented emittance (down to 10^{-8} m rad)
  - Sub-μm spot size
  - fs pulses

'Trojan Horse Technique'



Leverages efficiency and rep rate of conventional accelerators to produce beams with unprecedented brightness for collider & XFEL applications

Conclusion

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People who say it cannot be done should not interrupt those who are doing it.

George Bernard Shaw